INSTRUCTIONS

GEK-49871 A
Supersedes GEK-49871

STATIC PHASE
MHO DISTANCE RELAY
TYPE SLY63A

GENERAL ELECTRIC

CONTENTS

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TYPE SLY63A

DESCRIPTION

The SLY63A relay is a three-phase static mho distance relay with provision for offsetting the mho characteristic. The SLY63A is a rack mounted unit, two rack units high. It requires other fault detecting relays, an SSA power supply, SLA logic unit(s), SLAT output unit(s), and a test panel to provide a complete scheme.

APPLICATION

The type SLY63A static distance relay with its offset mho characteristic is applied primarily to provide the carrier starting (i.e. blocking) function in directional comparison pilot-relaying schemes. The relay will provide protection against all multi-phase faults that fall within its reach setting.

The SLY63A relay is not intended for use by itself, but rather is meant to be used as part of a complement of equipment to complete a protective relaying scheme. The additional relays and other equipment required to complete a specific scheme are dependent on the nature of the scheme and are described in the logic description that accompanies the overall logic diagram for that particular scheme.

In a directional comparison blocking scheme, the blocking (carrier starting) functions at a given terminal must be able to detect all external faults in back of that terminal that are within the reach of the tripping (MT) functions at the remote terminal(s) of the protected line. Any effects of arc resistance that may be present must also be included. If this were not so, carrier would not be started for certain external faults, a blocking signal would not be sent, and the remote MT functions would initiate a false trip.

With reference to the above, it should be recognized that fault resistances that are relatively large as compared to the relay settings will generally occur on short lines where increased reach settings of both the tripping and blocking functions introduce no load-limiting problems. On long lines, the arc resistance tends to be smaller relative to the relay settings so that any reasonable setting of MB will suffice.

The reach settings for the SLY63A will depend on the specific application. Thus, for any given equipment, the description of the scheme that accompanies the logic diagram should be consulted for specific recommendations concerning the settings.

In order to actually make the settings discussed above, it is necessary to select basic tap settings and percent restraint settings. In general, the sensitivity of the MB function increases as the base reach is raised. Therefore, it is recommended that the highest base reach setting that will accommodate the desired reach setting should be used. In selecting the base reach setting for the reach in the blocking direction, it is necessary that the tap selected be at least equal to, and preferably greater than, the base reach setting used in the MT function at the remote end of the line. This must be done even if it means setting a larger circle diameter than initially contemplated. If this procedure is followed, the MB function in this relay will automatically coordinate with the MT function at the remote end of the line.

On three-terminal lines, the same general considerations apply. The blocking function must detect all faults outside the protected area that can be detected by the MT tripping functions at the remote terminals. The application is more complex and the effects of infeed must be considered in setting the MT functions. Consequently, the settings of the blocking functions will be affected accordingly. Infeed affects the apparent impedance seen by the MT functions and the fault can appear to be further away impedance-wise than it actually is. Increase in the infeed leads to an increase in the apparent impedance and consequently to an increase in the required reach settings of the MT functions. With infeed removed, the MT functions will reach considerably farther beyond the remote terminals. This must be considered in setting the blocking functions if they are not to be outreached by the tripping functions during zero infeed conditions.

There is a certain amount of flexibility in the recommended settings. In general, the larger the setting of the MB function relative to the remote MT function, the more secure will be the application. In any case, the MB function should not be set so big that maximum load and/or minor system swings will cause the MB function to produce an output.

RATINGS

This relay is designed for use in an environment where the air temperature outside the relay case is between -20°C and +65°C.

Forms of the SLY63A are available for either 50 or 60 hertz applications.

Forms of this relay are available with current circuits rated for either five amperes or one ampere for continuous duty and have a one-second rating of 300 or 60 amperes respectively.

The potential circuits are rated for 120 volts.

The relay requires a ±15 VDC power source which may be obtained from type SSA power supplies.

Refer to the unit nameplate for the frequency and current ratings for a particular relay.

RANGES

The SLY63A relay has an adjustable reach of 0.1 to 30 ohms in the blocking direction for the five-ampere rated relay or 0.5 to 150 ohms for the one-ampere rated relay. The relay has a selectable offset in the tripping direction of 0.0, 0.1, 0.2, 0.3 or 0.4 per unit of the reach in the blocking direction.

Current input connections to establish the basic ohmic tap of one and three ohms line-to-neutral (five-ampere relay) or 5 and 15 ohms (one-ampere relay) are available at the current input terminals. Restraint taps in the voltage circuit range between 10 and 100 percent in one percent increments. In addition to the current input taps, the relay has a selectable base reach multiplier of 1.0, 0.5, 0.2 or 0.1 per unit.

The relay has a base reach angle which can be set for 85 or 75 degrees.

The polarizing voltage has an adjustable phase shift relative to the operating quantity of zero or fifteen degrees lead.

BURDENS

The maximum potential burden per phase, measured at 120 volts rms is:

60 Hz Relay	50 Hz Relay	
0.35	0.45	Volt-ampere
0.28	0.34	Watt
0.20	0.29	Var

The maximum phase current burden per phase is:

Five Ampere Relay		One Ampere Relay	
1 or 3 Ω Tap		5 or 15 Ω Tap	
Z: $0.026 \angle 7.3^{\circ}$	Ohms	Z: $0.117 \angle 1.6^{\circ}$	Ohms
R: 0.025	Ohms	R: 0.117	Ohms
X: 0.003	Ohms	X: 0.003	Ohms

The maximum burdens that the logic circuits present to the power supply are:

0.287	Ampere to the +15 VDC supply
0.122	Ampere to the -15 VDC supply

SENSITIVITY

Sensitivity is defined as the steady state rms voltage or current, measured at the relay terminals, required for a particular quantity to cause the relay to operate if all input quantities are in the optimal phase relationship. The nominal sensitivities for the signal quantities in the SLY63A relay are as follows:

OPERATING CIRCUIT SENSITIVITY

For phase pair A-B, the current sensitivity can be determined from the relationship:

$$(I_A - I_B)Z_{R1} = \frac{0.14}{1-X}$$

where

$$X = \frac{\text{Actual Relay Reach}}{\text{Nominal Relay Reach}}$$

For example, if $Z_{R1} = 3\Omega$ and $X = 0.9$, then:

$$(I_A - I_B) = 0.47 \text{ ampere}$$

For a phase-to-phase fault, $I_A = (I_A - I_B)/2$ or 0.23 ampere. For a three phase fault, $I_A = (I_A - I_B)/\sqrt{3}$ or 0.27 ampere.

POLARIZING CIRCUIT SENSITIVITY

Sensitivity is one percent of rated voltage.

OPERATING PRINCIPLES AND CHARACTERISTICS

GENERAL

The offset mho characteristic of the relay is illustrated in Fig. 1. This MB characteristic is a circle that does not pass through the origin of the IR-IX diagram. All measurements are made on a phase-to-phase basis (V_{a-b} is compared with $I_a - I_b$) in order to obtain the same relay reach for a phase-to-phase, a double phase-to-ground or a three-phase fault.

The mho characteristic is obtained by converting relay currents into voltage signals (IZ), combining these IZ signals with signals proportional to the line voltage (V), and measuring the phase angle between the appropriate combinations to obtain the desired characteristic.

Currents are converted into IZ signals by means of transactors (TE, TG and TJ); that is, air gap reactors with secondary windings. The transactors in this equipment are tapped on the primary to obtain the basic ohmic tap connection (one and three ohms).

The Z of the IZ quantity is the transfer impedance of the transactor, i.e. V_{OUT}/I_{IN}. The transactor secondaries have loading resistors across them. These resistors provide the desired angle between V_{OUT} and V_{IN}. This angle determines the angle of maximum reach of the relay.

The offset mho characteristic of Fig. 1 is obtained by comparing the phase angle between the quantities ($IZ-TV_R$) and ($IZP+TV$) where V is the phase-to-phase voltage at the relay, V_R is the phase-to-phase voltage plus K times the positive sequence voltage at the relay, I is the phase-to-phase current, TP is the relay base reach in the tripping direction, Z is the relay base reach in the blocking direction and T is the voltage restraint tap. For a circular characteristic, relay operation occurs when the angle B between ($IZ - T_{VR}$) and ($IZP + TV$) is less than or equal to 90 degrees.

RELAY REACH

The base reach of the relay in the blocking direction (Z_{R1}) is determined by the base ohmic tap (BOT) and the base reach multiplier (BRM); it is equal to the product of these two quantities; i.e.,

$$Z_{R1} = (BOT)\ (BRM) \qquad \text{(Eq. 1)}$$

where: Z_{R1} = base reach

BOT = base ohm tap

BRM = base reach multiplier

The reach of the relay in the blocking direction, Z_R, is directly proportional to the base reach of the function Z_{RI}, and inversely proportional to the restraint tap setting, T, i.e.,

$$Z_R = \frac{(Z_{R1})\ (100)}{(T)} = \frac{(BOT)\ (BRM)\ (100)}{(T)} \qquad \text{(Eq. 2)}$$

where: Z_R = relay reach

T = restraint tap setting in percent

conversely:

$$T = \frac{(Z_{R1})\ (100)}{(Z_R)} \qquad \text{(Eq. 3)}$$

This equation is more commonly used because Z_{R1} and Z_R are generally known, and T is the quantity that must be calculated.

The relay can be offset with an ohmic reach that is equal to a percentage (P) of the reach in the blocking direction; i.e.,

$$\text{Offset} = \frac{(P)\ (Z_{R1})\ (100)}{(T)} = (Z_R)\ (P) \qquad \text{(Eq. 4)}$$

where: P = per unit offset factor, and other terms are defined above.

The suggested range of adjustment for the restraint tap setting is 10 to 100 percent in one percent steps. Settings lower than 10 percent are not recommended.

ANGLE OF MAXIMUM REACH

The relay base reach angle is adjustable by means of links on the rear of the unit. The base reach angle can be set for either 85 or 75 degrees.

The polarizing quantity used to develop the mho characteristic can be phase shifted relative to the operating quantity. The phase shift can be set for either zero or 15-degree lead. For a circular characteristic, the 15-degree setting results in a clockwise shift in the angle of maximum reach away from the base reach angle. The angle of maximum reach is equal to the base reach angle minus the polarizing phase shift. The 15-degree setting increases the reach at the relay angle of maximum reach by the factor 1/cos (15^{o}) which is equal to 1.035.

PHASE ANGLE MEASUREMENT

The operating quantities ($IZ-TV_R$) and (IZP+TV) are fed into a filter card (F156 or F167). These cards filter out extraneous frequencies from the input quantities and produce square wave outputs. The phase relationship between these square waves is the same as that between the input quantities ($IZ-TV_R$) and (IZP+TV). The coincidence of these square waves (coincidence is defined as having the same polarity) is determined by a coincidence logic circuit (C104). The output of the coincidence logic circuit is a pulse whose width is equal to the coincidence of the two square waves and thereby has a direct relationship to the phase angle between the square waves. The last function in the phase angle measurement circuit is a timer (T121) which measures the duration of the pulse produced by the coincidence logic. If the timer is set to pick up on a pulse of 4.17 milliseconds (90 degrees) a circular characteristic is generated. If the timer setting is less than 4.17 milliseconds, an expanded circle is generated. Refer to Fig. 1. In this case, the angle between ($IZ-TV_R$) and (IZP+TV) (Fig. 1) is greater than 90 degrees.

SHAPE OF THE MB CHARACTERISTIC

If the angle of maximum reach is set for 75 or 85 degrees in the tripping direction (255 or 265 degrees in the blocking direction), the MB characteristic is symmetrical about the angle of maximum reach for all timer settings. A characteristic timer setting of 4.16 milliseconds produces a circular characteristic. The effects of characteristic timer settings greater or less than 4.16 milliseconds are shown in Fig. 1-a.

Figure 1-b shows the effect of the 15-degree polarizing phase shift and a characteristic timer setting less than 4.16 milliseconds. Similarly, an asymmetrical lens characteristic would be produced by a timer pickup setting greater than 4.16 milliseconds.

CIRCUIT DESCRIPTION

The internal connections of the SLY63A relay are shown in Fig. 2. The voltage inputs are on the upper left of the diagram. The current inputs are on the lower left. The YE and YF designations refer to twelve point terminal blocks located on the rear of the unit. The component and card locations are shown on the diagram of Fig. 3.

The phase-to-phase input voltages are passed through transformers (TA, TB, TC) with one percent taps on the secondary. This voltage is then fed to the processing card in location D and into the operating circuit of one of the three filtering cards. The voltage is inverted on the processing card and then fed to the polarizing circuit of the filter card.

The input phase currents are passed through transactors (TE, TG, TJ). The three resulting voltages are then fed to the processing card in location E. This card develops three phase-to-phase IZ quantities, the Z of which can be changed by means of the base reach multiplier (BRM) selector located on the card. The base reach multiplier selector sets the Z of all three IZ quantities with one adjustment. The outputs of the card are fed to the operating circuit of the appropriate filter card where it is added to the phase-to-phase voltage signal to form the (IZP+TV) quantity. The output is also fed to the processing card in location F. The per unit offset reach (P) selector is located on this card. The output of this card is then fed to the polarizing circuit of the appropriate filter card where it is used to form the ($IZ-TV_R$) quantity.

The filter cards are used to filter the AC signals and to produce square waves whose phase relationship is the same as between the quantities ($IZ-TV_R$) and (IZP+TV). These two square waves are then fed into the coincidence logic circuit (L,M,N). The coincidence logic produces a +15 VDC output whenever the two input signals have the same polarity. The pulse width of the card output is proportional to the phase angle between ($IZ-TV_R$) and (IZP+TV). The width of the pulse is measured by the timing circuit on the timer card (P,R,S). The timer card produces an output whenever the fault falls within the MB characteristic. The circuitry for all three phase pairs is the same.

CALCULATION OF SETTINGS

The suggested settings for the MB functions used in a particular application can be found in the logic description supplied with the scheme. The following is supplied to tabulate the required settings, and to show how these settings can be calculated.

The following settings must be made:

1. Base ohm tap, BOT. Available taps are one ohm or three ohms for five-ampere rated relays; and five ohms or 15 ohms for one-ampere rated relays.
2. Base reach multiplier, BRM. Available multipliers are 0.1, 0.2, 0.5 and 1.0.
3. Restraint tap setting, T. Suggested range of settings is 10 to 100 percent in one-percent steps.
4. Offset reach tap, P. Available taps are 0, 0.1, 0.2, 0.3 and 0.4.
5. Angle of maximum reach, 85 degrees or 75 degrees. The following is suggested. Use the 85 degree setting for lines having positive sequence impedance angles greater than 80 degrees. Use the 75 degree setting if the angle of the positive sequence line impedance is less than 80 degrees.

In making any setting, it is first necessary to determine a base reach setting Z_{R1}, which can be calculated as follows:

$$Z_{R1} = (BOT)\ (BRM)$$

The available base reach settings are given in the following table.

Z_{R1}	BOT	BRM
0.1	1	0.1
0.2	1	0.2
0.3	3	0.1
0.5	1	0.5
0.6	3	0.2
1.0	1	1.0
1.5	3	0.5
3.0	3	1.0

In making a particular setting, always select the maximum available base reach that is less than the reach desired of the function. By doing this, maximum sensitivity will be obtained.

For purposes of demonstration, consider a 75 mile, 230 kV transmission line, and assume the following:

$Z_1' = 52\underline{/86^o}$ ohms (primary)

$Z_0' = 130\underline{/74^o}$ ohms (primary)

CT ratio = 1200/5 - 240

PT ratio = 230000/115 - 2000

Converting to secondary ohms:

$$Z_1' = (52)\frac{(240)}{(2000)} = 6.24 \text{ ohms (secondary)}$$

$$Z_0' = (130)\frac{(240)}{(2000)} = 15.6 \text{ ohms (secondary)}$$

The suggested MB setting for a 75 mile line is a forward reach of 250 percent of the positive sequence line impedance (2.5 x Z_1'). The term "forward" applies to the reach in the blocking direction; i.e., looking away from the protected line. An offset reach equal to 30 percent of the forward reach is also suggested.

The forward reach is obtained by calculating the desired reach, selecting a suitable base reach, and then calculating the required restraint tap setting, T, as follows:

$$T = \frac{(Z_{R1})\ (100)}{(Z_R)} \qquad \text{(Eq. 5)}$$

where: T = restraint tap setting in percent

Z_{R1} = base reach = (BOT) (BRM)

Z_R = desired reach in blocking direction in positive sequence secondary ohms.

For the assumed line, and suggested settings,

$$Z_R = (2.5)\ (Z_1') = (2.5)\ (6.24) = 15.6 \text{ ohms}$$

The maximum available base reach that is less than Z_R is three ohms; i.e., BOT =3 and BRM = 1, then,

$$T = \frac{(3)\ (100)}{(15.6)} = 19.2 \text{ percent}$$

Use the 19 percent restraint tap.

Set the offset tap, P, at 0.3 which yields an offset of (0.3) (15.6) - 4.68 ohms.

Set the maximum reach angle at 85 degrees.

CONSTRUCTION

The Type SLY63A relay is packaged in a metal enclosure designed for mounting on a 19-inch rack. The relay is two rack units high (one rack unit is 1-3/4 inches). The outline and mounting dimensions are shown in Fig. 4. The relay contains the magnetics and tap blocks for setting the base reach and the percent restraint. It also contains the printed circuit cards for developing three phase-to-phase mho blocking characteristics. The relay has a hinged front cover and a removable top cover.

The current input setting is accomplished by the connection of the input currents to the YE and YF terminal boards on the rear of the relay. The connection points for the one and three-ohm taps are shown in the table on the internal connection diagram of Fig. 2.

The voltage restraint tap blocks are located on the front of the unit at the left hand side. Refer to the component location diagram of Fig. 3. The voltage restraint tap settings are made by jumpers with taper tip pins on the end. Two special tools are supplied for these pins in the accessory kit accompanying each equipment. One is an insertion tool and the other is an extraction tool. In order to achieve a better connection and not to damage the pins, it is essential that these tools be used. Two tap blocks are used per phase: one is for the ten percent tap and one is for the one percent tap. The voltage restraint tap setting is the sum of the one and ten percent settings.

The relay also contains printed circuit cards which are located to the right of the tap blocks. The printed circuit cards are identified by a code number such as F125, C105, T133 or P102 where F designates filter, C designates coincidence, T designates time delay, and P designates processing. The printed circuit cards plug in from the front of the unit. The sockets are identified by letter designations or "addresses" (D, E, F etc.) which appear on the guide strips in front of each socket, on the component location diagram, on the internal connection diagram and on the printed circuit card itself.

RECEIVING, HANDLING AND STORAGE

These relays will normally be supplied as a part of a static relay equipment, mounted in a rack or cabinet with other static relays and test equipment. Immediately upon receipt of a static relay equipment, it should be unpacked and examined for any damage sustained in transit. If injury or damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Sales Office.

Reasonable care should be exercised in unpacking the equipment. If the equipment is not to be installed immediately, it should be stored indoors in a location that is free from moisture, dust, and metallic chips, and severe atmospheric contaminants.

Just prior to final installation the shipping support bolt should be removed from each side of all relay units, to facilitate possible future unit removal for maintenance. These shipping support bolts are approximately eight inches back from the relay unit front panel. Static relay equipment, when supplied in swing rack cabinets, should be securely anchored to the floor or to the shipping pallet to prevent the equipment from tipping over when the swing rack is opened.

INSTALLATION TESTS

CAUTION

THE LOGIC SYSTEM SIDE OF THE DC POWER SUPPLY USED WITH MOD III STATIC RELAY EQUIPMENT IS ISOLATED FROM GROUND. IT IS A DESIGN CHARACTERISTIC OF MOST ELECTRONIC INSTRUMENTS THAT ONE OF THE SIGNAL INPUT TERMINALS IS CONNECTED TO THE INSTRUMENT CHASSIS. IF THE INSTRUMENT USED TO TEST THE RELAY EQUIPMENT IS ISOLATED FROM GROUND, ITS CHASSIS MAY HAVE AN ELECTRICAL POTENTIAL WITH RESPECT TO GROUND. THE USE OF A TEST INSTRUMENT WITH A GROUNDED CHASSIS WILL NOT AFFECT THE TESTING OF THE EQUIPMENT. HOWEVER, A SECOND GROUND CONNECTION TO THE EQUIPMENT, SUCH AS A TEST LEAD INADVERTENTLY DROPPING AGAINST THE RELAY CASE MAY CAUSE DAMAGE TO THE LOGIC CIRCUITRY. NO EXTERNAL TEST EQUIPMENT SHOULD BE LEFT CONNECTED TO THE STATIC RELAYS WHEN THEY ARE IN PROTECTIVE SERVICE, SINCE TEST EQUIPMENT GROUNDING REDUCES THE EFFECTIVENESS OF THE ISOLATION PROVIDED.

GENERAL

The test points (TP1, TP2, etc.) shown on the internal connection diagram are connected to instrument test jacks on a test card in card location T. TP1 is located at the top of the card and is connected to relay reference. TP10 is located at the bottom of the card and is connected to +15VDC. Output signals are measured with respect to the relay reference (TP1). Logic signals are approximately +15VDC for the ON or LOGIC ONE condition, and between 0 and +1VDC for the OFF or LOGIC ZERO condition. Filter card outputs are square waves which shift from +15V to -15V.

Any of the input/output pins on the printed circuit boards can be monitored by using the test card adapter as described in the printed circuit card instruction book GEK-34158. The logic signals can be monitored with an oscilloscope, a portable high impedance voltmeter or the voltmeter on the equipment test panel. When the test panel meter is supplied, it will normally be connected to relay reference. Placing the test lead to the proper test point will connect the meter for testing. When time-delay cards are to be adjusted or checked, an oscilloscope, which can display two traces simultaneously and which has a calibrated horizontal sweep, should be used.

The relay contains printed circuit cards with trimmer potentiometers mounted on them. Some of these potentiometers are factory set and sealed. These potentiometers should not be readjusted.

Before testing the relay, the trip outputs from the associated Type SLAT relay should be opened to prevent inadvertent tripping of the breakers.

Input currents and voltages may be supplied to the relay through Type XLA test plugs placed in the test receptacles on the equipment test panel. Reference to the elementary diagram for the static relay equipment will provide information concerning equipment inputs. All units of a given terminal have been calibrated together at the factory and will have the same summary number on the unit nameplates. These units should be tested and used together.

NECESSARY ADJUSTMENTS

The following checks and adjustments should be made by the user in accordance with the procedures given under DETAILED TESTING INSTRUCTIONS before the relay is put into service. The necessary set points may be calculated following the procedures under CHOICE AND CALCULATION OF SETTINGS. The adjustments should be made in the order shown.

1. Base reach setting (Z_R, P)
   a) Current input tap selection (BOT)
   b) Base reach multiplier selection (BRM)
   c) Per unit offset reach selection (P)
2. Voltage restraint tap setting (T)
3. Angle of maximum reach setting
4. Characteristic timer setting
5. Reach vernier adjustment
6. MB characteristic plot

DETAILED TESTING INSTRUCTIONS

RELAY BASE REACH

The basic ohmic tap (BOT) is determined by the terminals to which the relay input currents are connected to the relay. The correct input terminals for the one and three-ohm current input taps are given in Table I.

TABLE I

	IA		IB		IC	
BASE OHMS	IN	OUT	IN	OUT	IN	OUT
1 OHM	YF8	YE4	YF9	YE6	YF10	YE8
3 OHM	YF8	YE3	YF9	YE5	YF10	YE7

The base reach multiplier selector is located on the card in location E. The adjustment is accomplished by a four position jumper block. In each position the gain of the IZ circuit for each phase pair is set to the proper value of base reach multiplier. The base reach multiplier for each jumper position on the card is shown in Table II.

TABLE II

JUMPER POSITION	BASE REACH MULTIPLIER (BRM)
B	1.0
C	0.5
D	0.2
E	0.1

The per unit offset reach selector is located on the card in location F. The adjustment is accomplished by a five position jumper block. In each position the gain of the IZ circuit for each phase is set to the proper value of per unit offset reach multiplier. The per unit offset reach for each jumper position on the card is shown in Table III.

TABLE III

JUMPER POSITION	PER UNIT OFFSET REACH (P)
A	0.0
B	0.1
C	0.2
D	0.3
E	0.4

The relay base reach in the blocking direction (Z_{R1}) is given by Equation 1. The relay reach in the blocking direction (Z_R) is given by Equation 2; the offset reach, by Equation 4.

VOLTAGE RESTRAINT TAP SETTING

The voltage restraint tap setting (T) is accomplished on the tap blocks located on the front of the relay. A separate tap block is provided for each phase pair. The setting consists of a ten percent tap and a one percent tap. A restraint tap setting of 57 percent would consist of a ten percent setting of 50 and a one percent setting of seven. Only the special tools supplied with the relay should be used to change the tap setting. The reach of the relay at 255 degrees is given by Equation 3 or 4. The reach of the relay at 75 degrees is given by Equation 6 or 7.

ANGLE OF MAXIMUM REACH SETTING

The base reach angle is adjusted by means of links on the rear of the relay. The angle can be set for 75 or 85 degrees.

In order to set the polarizing voltage phase shift, it is necessary to adjust the X option plus on the filter cards in card locations H, J and K. The setting must be made on each of the three cards. The polarizing voltage phase shift for each position is shown in Table IV.

TABLE IV

PLUG X SHORTING ARRANGEMENT	DEGREES OF LEADING PHASE SHIFT
2 to 3 and 4 to 5	0
1 to 2 and 3 to 4	15

The polarizing phase shift may be checked and, if necessary, adjusted by using the test circuit of Fig. 7 and the appropriate connections of Table V. Note that only voltage is applied to the relay for this test. The following procedure is recommended:

1) Start with the phase A connections of Table V. Set the voltage restraint tap for 100 percent. Adjust the voltage for 30 Vrms.

TABLE V

PHASE PAIR	FIG. 5 CONNECTIONS			FILTER CARD LOCATION
	A	B	JUMPER POINTS	
A-B	YF2, YF7	YF3, YF4	YF5 to YF6	H
B-C	YF4, YF3	YF5, YF6	YF2 to YF7	J
C-A	YF6, YF5	YF7, YF8	YF3 to YF4	K

2) Observe the output at pins 8 and 9 of the filter card in location H for phase A-B. The following phase angle measurements should be made using a dual trace oscilloscope with a calibrated sweep sufficiently fast to provide an accurate measurement and with both traces carefully zeroed on the center line. Refer to Fig. 8 for sample waveforms.

3.A) Zero Degree Polarizing Phase Shift

The square waves at pins 8 and 9 of the filter card should be exactly 180 degrees out of phase, i.e. the zero crossings of each trace should coincide at the center line and the traces should have opposite slopes. The phase shift between pin 8 and pin 9 may be adjusted by potentiometer P71 on the filter card.

B) Fifteen Degree Polarizing Phase Shift

The square wave at pin 9 is now shifted 15 degrees in the leading direction (toward the left-hand edge of the screen.) The zero crossings of the square waves should now occur 15 degrees apart (0.694 milliseconds on a 60 hertz base, 0.833 milliseconds on a 50 hertz base). Refer to Fig. 8.

The phase shift between pins 8 and 9 may be adjusted by potentiometer P71 on the filter card.

4. Repeat steps 1, 2 and 3 for phase pairs B-C and C-A. Observe the outputs of the filter card associated with the phase under test. Use the appropriate connections from Table V.

CHARACTERISTIC TIMER SETTING

The pickup setting of the characteristic timer affects the shape of the MB characteristic. Increasing the pickup time tends to narrow the characteristic, decreasing the pickup time widens the characteristic. The reset time delay (drop-out time) provides an overlap of the next half-cycle measurement and provides a time delay before resetting after the input signal is removed. The inputs of the timers are +15V pulses whose width is proportional to the phase angle between ($IZ-TV_R$) and($IZP+TV$). One pulse occurs every half cycle. The outputs of the timers are DC logic signals. The timer settings are discussed in the section CALCULATIONS OF SETTINGS.

The timers used for the MB function are integrating characteristic timers. These timers are typically listed on the overall logic as T1, T2/T3 where T1 is the pickup time in milliseconds on a step DC input, T2 is the pulse width which will cause the timer to pick up with one pulse applied per half cycle and T3 is the drop-out delay. The operation of the integrating characteristic timers is discussed in the printed circuit card instruction book, GEK-34158.

The DC pickup (T1) and the dropout (T3) of the MB characteristic timer may be set using the test circuit of Fig. 6. Before testing the timer with this circuit, the card which normally supplies the input to the timer must be removed (refer to Table VI). Opening the normally closed contact of Fig. 6 causes the output to step to +15VDC after the pickup delay of the timer. To increase the pickup delay, turn the upper potentiometer (P1) on the timer card clockwise. Closing the contact causes the timer to drop out (step to less than one VDC) after the reset delay setting of the card. To increase the reset delay, turn the second potentiometer (P2) clockwise. The pulse pickup mode of the timer may be observed while plotting the characteristic as described in OVERALL CHECK OF THE MB CHARACTERISTIC. The applied voltage and current as well as the phase angle between them, can be adjusted to vary the pulse width of the timer input.

TABLE VI

TIMER UNDER TEST	REMOVE CARD
P	L
R	M
S	N

OVERALL CHECK OF THE MB CHARACTERISTIC

An overall check of the MB characteristic can be made by applying current and voltage to the relay and plotting the MB characteristic on an R-X (ohms) or IR-IX (voltage) diagram. This plot may be compared with a theoretical characteristic plotted following the directions given in the section SHAPE OF THE MB CHARACTERISTIC.

The MB characteristic may be checked using the test circuit of Fig. 7. The connections for testing each of the three phase pairs are listed in Table VII for the one ohm tap and Table VIII for the three ohm tap.

TABLE VII

PHASE PAIR	FIGURE 5 CONNECTIONS - 1 OR 5 OHM TAP						
	A	B	C	D	E	F	G
A-B	YF2, YF7	YF3, YF4	YF5, YF6	YE4	YF8	YF9	YE6
B-C	YF4, YF3	YF5, YF6	YF2, YF7	YE6	YF9	YF10	YE8
C-A	YF6, YF5	YF7, YF2	YF3, YF4	YE8	YF10	YF8	YE4

TABLE VIII

PHASE PAIR	FIGURE 5 CONNECTIONS - 3 OR 15 OHM TAP						
	A	B	C	D	E	F	G
A-B	YF2, YF7	YF3, YF4	YF5, YF6	YE3	YF8	YF9	YE5
B-C	YF4, YF3	YF5, YF6	YF2, YF7	YE5	YF9	YF10	YE7
C-A	YF6, YF5	YF7, YF2	YF3, YF4	YE7	YF10	YF8	YE3

Relay Base Reach Angle and Reach Check

The following procedure is recommended to check the base reach angle (A) and the relay reach setting.

1) Use the test circuit of Fig. 7 starting with the phase A-B connections from Table VII or VIII.

   Set the test current for a current equal to or greater than that specified in Table IX. Currents greater than twice rated should not be continuously applied to the relay. Currents greater than four times rated should not be applied to the relay. Currents between two and four times rated should not be applied longer than five minutes with an off time of at least five minutes.

TABLE IX

BASE REACH OHMS	RECOMMENDED MINIMUM TEST CURRENT (AMP) FOR LESS THAN 2% PULL BACK	
	FIVE AMPERE RELAY	ONE AMPERE RELAY
3.0	2	0.4
1.5	5	1.0
1.0	5	1.0
0.6	10	2.0
0.5	10	2.0
0.3	20	4.0
0.2	20**	4.0**
0.1	20**	4.0**

**Less than 5 percent pull back.

2) Adjust the phase angle for the nominal base reach angle (255 or 265 degrees).

3) Observe the output at pin 8 of the appropriate filter card (card location H for phase pair A-B, J for B-C, or K for C-A).

4) Lower the voltage to the value given by the following expression:

$$V_B = 2 \times I_T \times BOT \times BRM \times \frac{100}{T} \qquad \text{(Eq. 6)}$$

where:

BOT is the basic ohmic tap

BRM is the base reach multiplier

I_T is the test current

T is the voltage restraint tap setting in percent

V_B is the operating voltage at the base reach angle blocking direction.

5) As the voltage is lowered observe the output of the MB function: TP5 for phase pair A-B, TP7 for B-C or TP9 for C-A. At the point where MB picks up, a slight adjustment of the phase angle and voltage should cause the square wave at pin 8 of the filter card to come out of saturation. A further adjustment will cause the signal at pin 8 to be reduced to a null voltage consisting of only third and fifth harmonics. The angle on the phase angle meter is the base reach angle and should be within two degrees of the nominal setting. The voltage should be within five percent of the value given by Equation 6.

6) A vernier adjustment on the reach is provided on the filter card (position H, J, or K). Turning P10 on the appropriate filter card clockwise increases the voltage required to null the MB function, thereby increasing the relay reach.

Each filter card contains two factory adjusted and sealed potentiometers: P27 and P61. These potentiometers are used in setting the filter circuits used on the cards and should not be adjusted by the user.

7) Adjust the phase angle for the nominal base reach angle (75 or 85 degrees).

8) Observe the output at pin 9 of the appropriate filter card (card location H for phase pair A-B, J for B-C, or K for C-A).

9) Lower the voltage to the value given by the following expression:

$$V_T = 2 \times I_T \times BOT \times BRM \times \frac{100}{T} \times P \qquad \text{(Eq. 7)}$$

where:

P is the per unit offset reach

BOT is the basic ohmic tap

BRM is the base reach multiplier

I_T is the test current

T is the voltage restraint tap setting in percent

V_T is the operating voltage at the base reach angle offset direction.

10) As the voltage is lowered observe the output of the MB function: TP5 for phase pair A-B, TP7 for B-C or TP9 for C-A. At the point where MB picks up, a slight adjustment of the phase angle and voltage should cause the square wave at pin 9 of the filter card to come out of saturation. A further adjustment will cause the signal at pin 9 to be reduced to a null voltage consisting of only third and fifth harmonics. The angle on the phase angle meter is the base reach angle and should be within two degrees of the nominal setting. The voltage should be within five percent of the value given by Equation 7.

11) A vernier adjustment on the reach is provided on the filter card (position H, J, or K). Turning P52 on the appropriate filter card clockwise increases the voltage required to null the MB function, thereby increasing the relay reach.

12) Repeat steps 1 through 11 for phase pairs B-C and C-A using the connections from Table VII or VIII.

MB FUNCTION CHECK

The following procedure is recommended to provide an overall check of all the adjustments included in the MB function. It is only necessary to check the relay reach at two angles other than the base reach angle in both the tripping and blocking directions.

The table below gives the per unit pickup voltage at four points on the MB characteristic based on an offset tap of 0.3, a polarizing voltage phase shift of zero degrees, and a characteristic timer setting as listed.

Characteristic Timer Setting	Per Unit Pickup Voltage at Max. Reach Angle $\pm 30^{\circ}$ Blocking Direction	Per Unit Pickup Voltage at Max. Reach Angle $\pm 30^{\circ}$ Tripping Direction
3.8 ms	1.00	0.35
4.0 ms	0.96	0.33
4.2 ms	0.93	0.32
4.5 ms	0.87	0.30

Example 1:

(Two ohm reach in the blocking direction; taps chosen for optimum sensitivity)

Basic Ohmic Tap (BOT)	3 Ω
Base Reach Multiplier	0.5
Per Unit Offset (P)	0.3
Polarizing Voltage Phase Shift (B)	0°
Characteristic Timer Setting (C)	90° (4.2ms)
Voltage Restraint Tap (T)	75%
Positive Sequence Base Reach (A)	85°
Test Current (I_T)	5 Amperes

The operating voltage at the base reach angle in the blocking direction (265 degrees) is given by Equation 6.

$$V_A = 2 \times I_T \times BOT \times BRM \times \frac{100}{T}$$

$$V_A = 20V$$

The operating voltage (V_T) in the blocking direction at 235 and 295 degrees from the above table and settings is:

$$V_T = 0.93 \times V_A = 18.6 \text{ volts}$$

The operating voltage at 55 and 115 degrees is:

$$V_T = 0.32 \times V_A = 6.4 \text{ volts}$$

1) Use the test circuit of Fig. 6. Start with the A-B phase pair connections from Table VII or VIII. Set the current for the desired level (Table IX). Monitor the output at TP5 for phase pair A-B, TP7 for B-C, or TP9 for C-A.

2) Adjust the phase shifter for an above described angle.

3) Lower the applied voltage and check for an MB output within five percent of the voltage calculated as in the above example.

For offsets other than 0.3, polarizing voltage phase shift other than zero degrees, timer setting other than shown or additional points on the above described characteristics, the pickup voltage must be calculated by solving the following quadratic equations for the impedance.

$$Z^2 - Z\left[\frac{Z_R\ (P\sin\ (A-D+C-B) + \sin\ (A-D-C+B)}{\sin(C-B)}\right] - PZ_R^2 = 0 \qquad \text{(Eq. 8)}$$

for $(A-180^{o}) \leq D \leq A$

or $$Z^2 - Z\left[\frac{Z_R\ (P\sin\ (A-D-C-B) + \sin\ (A-D+C+B)}{\sin(-C-B)}\right] - PZ_R^2 = 0 \qquad \text{(Eq. 9)}$$

for $A \leq D < (A+180)$

where:

Z = Impedance at the test angle

A = Angle of maximum reach

B = Polarizating phase shift angle

C = Characteristic timer setting in degrees.

All other terms as previously defined.

D = Angle under test

The operating point voltage (V_D) at the angle under test is:

$$V_D = 2I_{TEST}\ Z \qquad \text{(Eq. 10)}$$

Example 2:

Assuming a relay reach of 1.35 ohms at 255 degrees, a polarizing phase shift of 15 degrees, a characteristic timer setting of 3.5 milliseconds and an offset of 0.2 per unit.

From the tables:

BOT = 1
BRM = 1
I_{TEST} = 5 amperes

and set:

Voltage restraint tap (T)
Polarizing phase shift (B) = 15^{o}
Characteristic timer (C) = 3.5 ms = 75^{o}

Check the MB reach angle and reach at 255 and 75 degrees as described in steps 1 through 11 above. Then for a test angle of 45 degrees calculate the impedance Z using Equation 8.

For this example:

$$Z^2 - Z\left[1.35\ \frac{(.2\ \sin(75-45+75-15)+\sin(75-45-75+15))}{\sin(75-15)}\right] \quad -0.2(1.35)^2$$

$$Z^2 - Z\left[1.35\ \frac{(.2\ \sin\ 90 + \sin -30)}{\sin\ 60}\right] = 0.3645$$

$$Z^2 + 0.4677Z - 0.3645 = 0$$

For a quadratic of the form:

$$Z^2 + bZ + C = 0$$

$$Z = \frac{-b \pm \sqrt{b^2 - 4\ c}}{2}$$

Therefore: $Z = 0.4136$ or -0.8813 (ignore negative roots)

and: $V_D = 2\ I_{TEST} \times Z = 4.136$ volts

Similarly, at a 225 degree test angle using Equation 9:

$Z = 1.23$ ohms

$V_D = 12.3$ volts

The MB function operating point can then be checked using steps 1 through 3 above.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

PERIODIC CHECKS

The MB functions included in the relay may be checked at periodic intervals using the procedures described in the DETAILED TESTING INSTRUCTIONS section. Cable connections between the relay and the associated Type SLA relay can be checked by observing the relay outputs at points in the SLA relay.

TROUBLE SHOOTING

In any troubleshooting equipment, it should first be established which unit is functioning incorrectly. The overall logic diagram supplied with the equipment shows the combined logic of the complete equipment and the various test points in each unit. By signal tracing, using the overall logic diagram and the various test points, it should be possible to quickly isolate the trouble.

A test adapter card (0149C7259G-2) is supplied with each static relay equipment to supplement the pre-wired test points on the test cards. Use of the adapter card is described in the card instruction book GEK-34158.

A dual-trace oscilloscope is a valuable aid to detailed troubleshooting, since it can be used to determine phase shift, operate and reset times as well as input and output levels. A portable dual-trace oscilloscope with a calibrated sweep and trigger facility is recommended.

SPARE PARTS

To minimize possible outage time, it is recommended that a complete maintenance program should include the stocking of at least one spare card of each type. It is possible to replace damaged or defective components on the printed circuit cards, but great care should be taken in soldering so as not to damage or bridge-over the printed circuit buses, or overheat the semiconductor components. The repaired area should be recovered with a suitable high-dielectric plastic coating to prevent possible breakdowns across the printed buses due to moisture and dust. The wiring diagrams for the cards in the relay are included in the card book GEK-34158; the card types are shown on the component location diagram, Fig. 7.

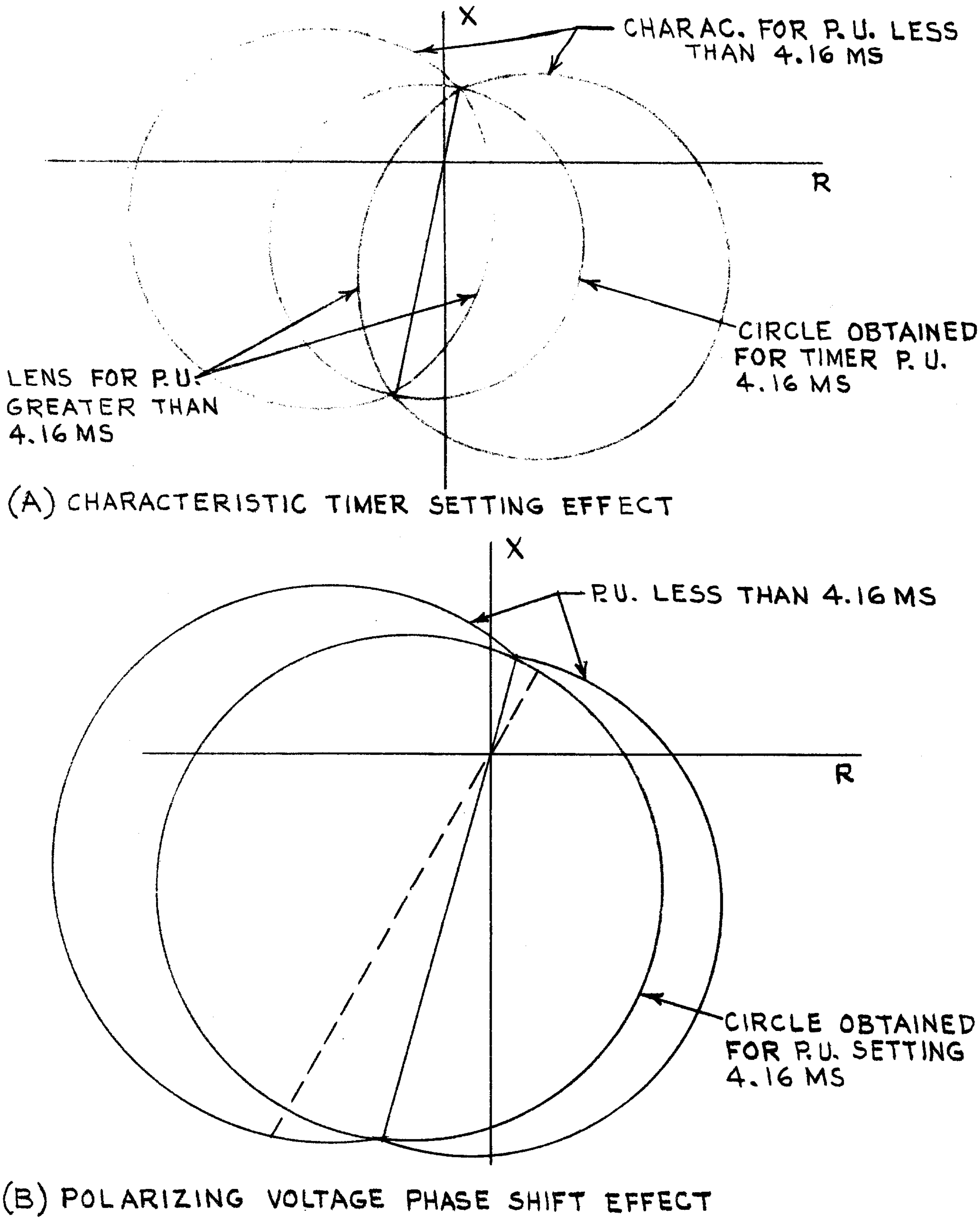


FIG. 1 (0275A3236-0) Offset Blocking Characteristic Variation with Pickup Timer and Polarizing Voltage Phase Shift

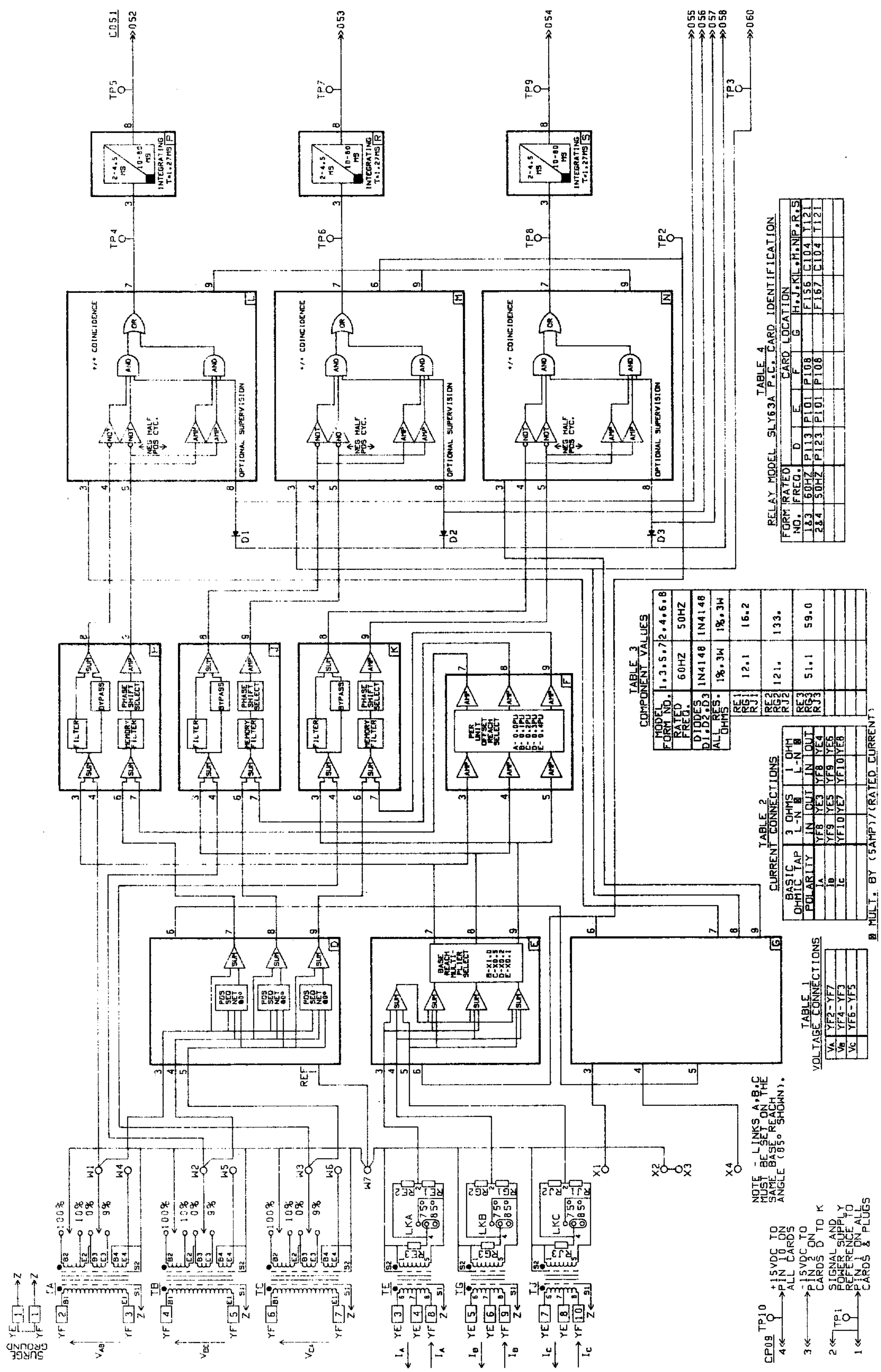


FIG. 2 (0136D4931-0) Internal Connections for the SLY63A Relay

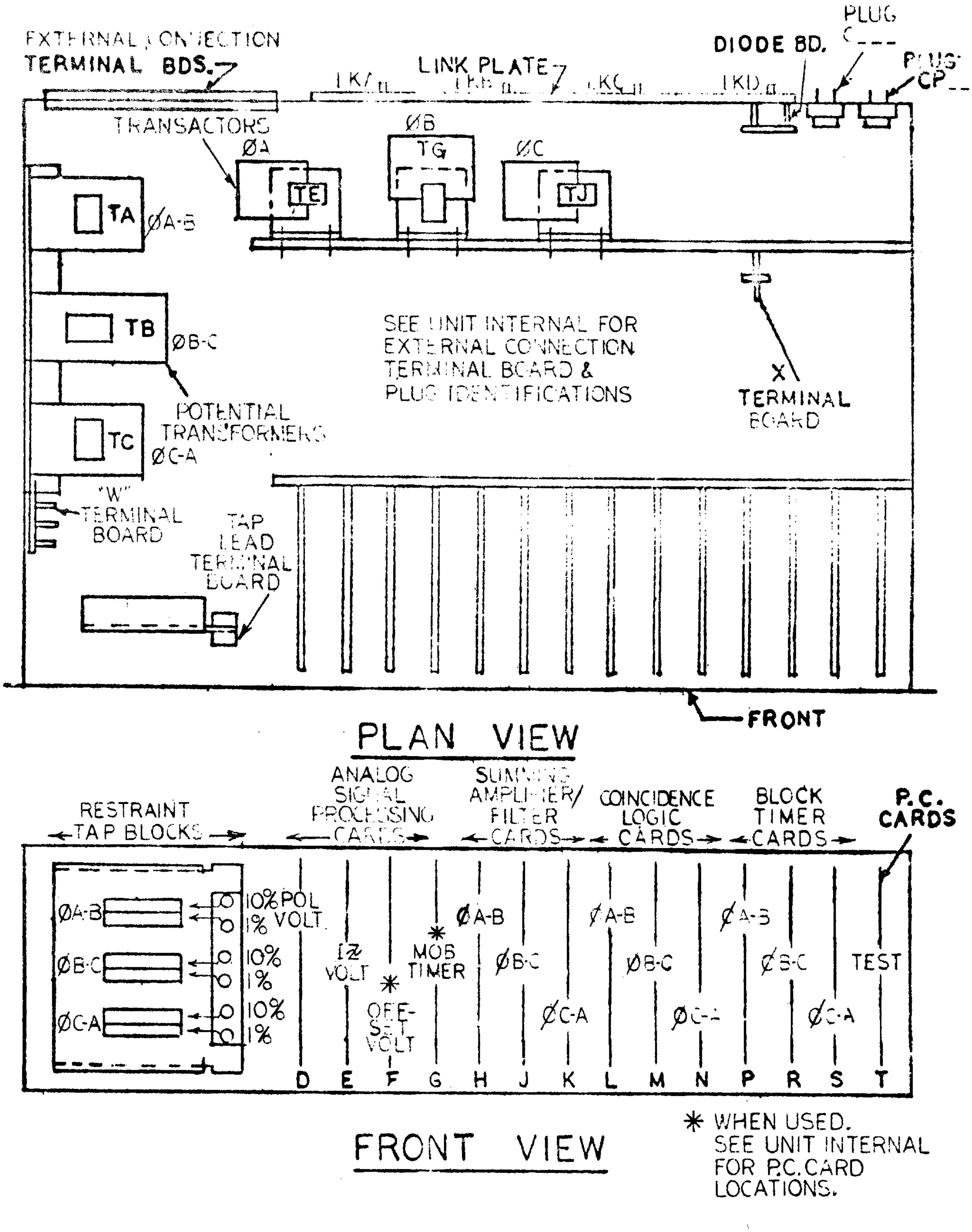


FIG. 3 (0269A3157-1) Component Location Diagram for the SLY63A Relay

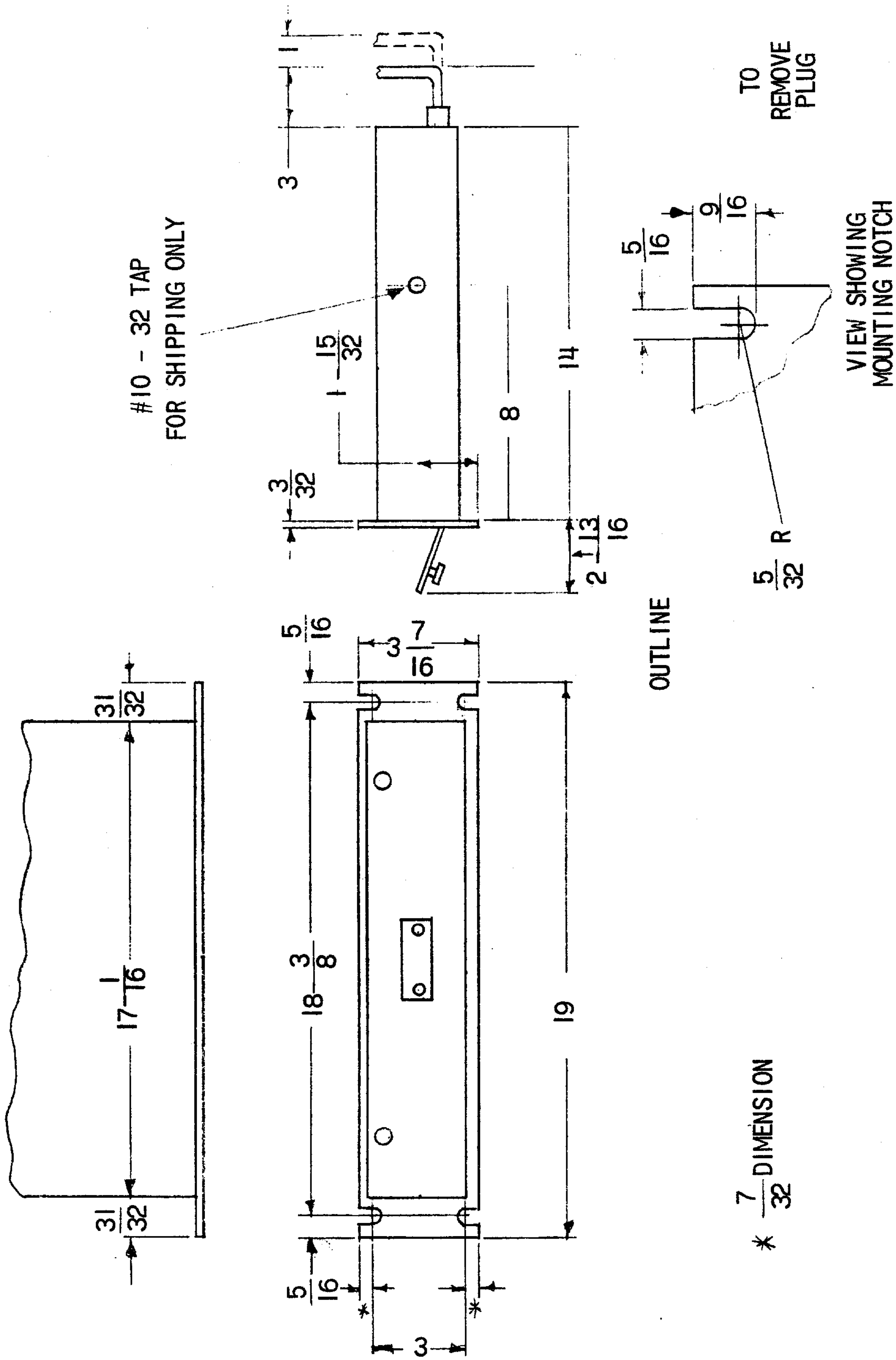


FIG. 4 (0227A2036-0) Outline and Mounting Dimensions for the SLY65A Relay

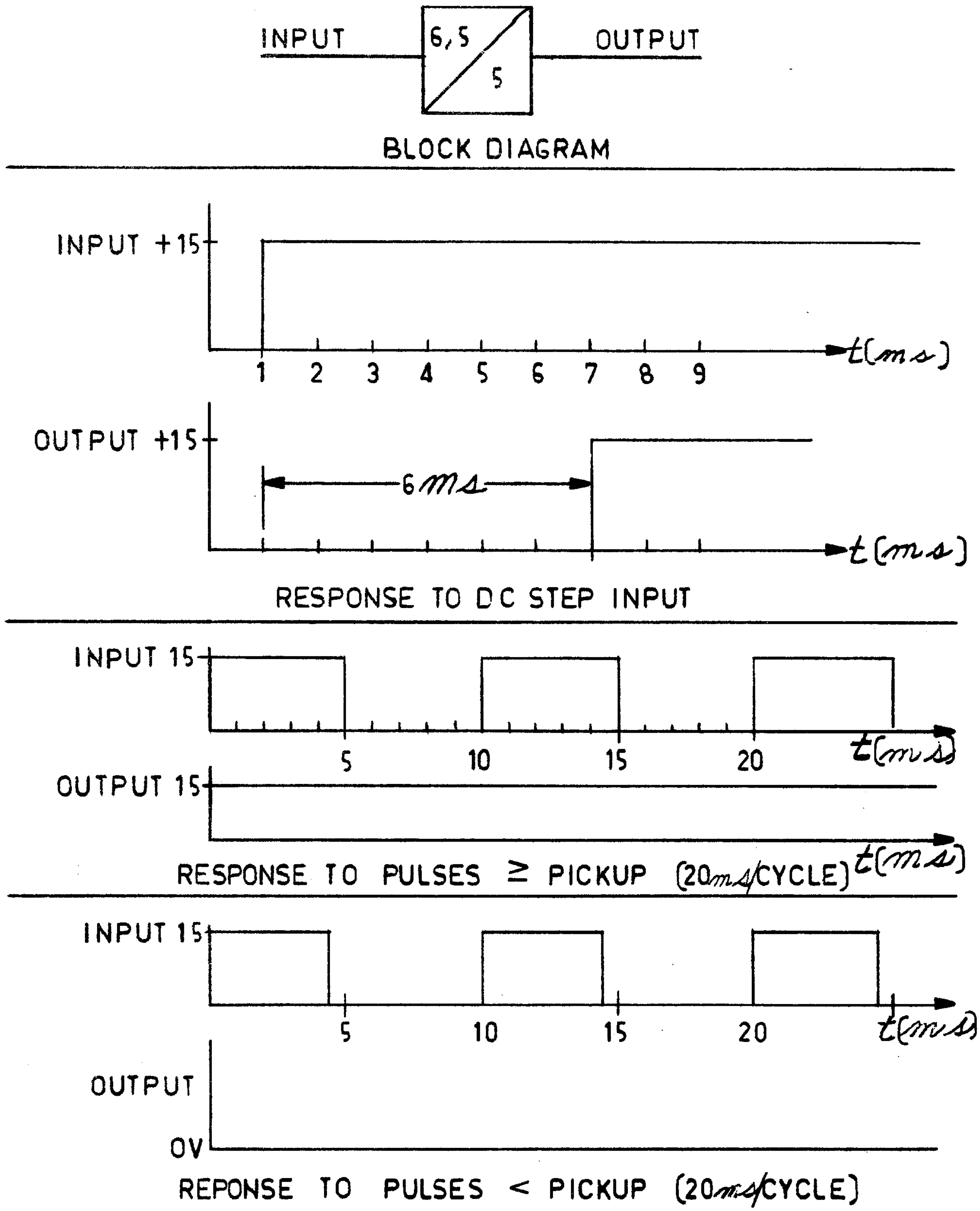
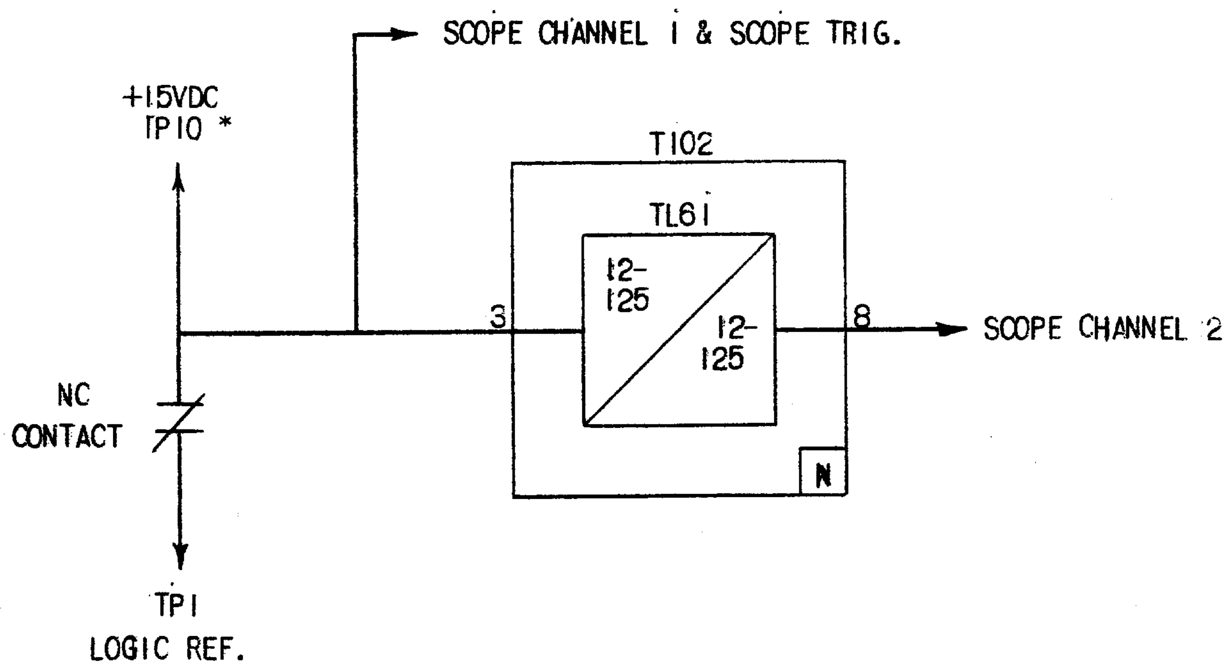


FIG. 5 (0257A9624-0) Integrating Timer Pickup Waveforms



* THE 15VDC SIGNAL AT PIN 10 HAS A CURRENT LIMITING RESISTOR MOUNTED ON THE TEST CARD.

FIG. 6 (0246A7987-0) Timer Test Circuit

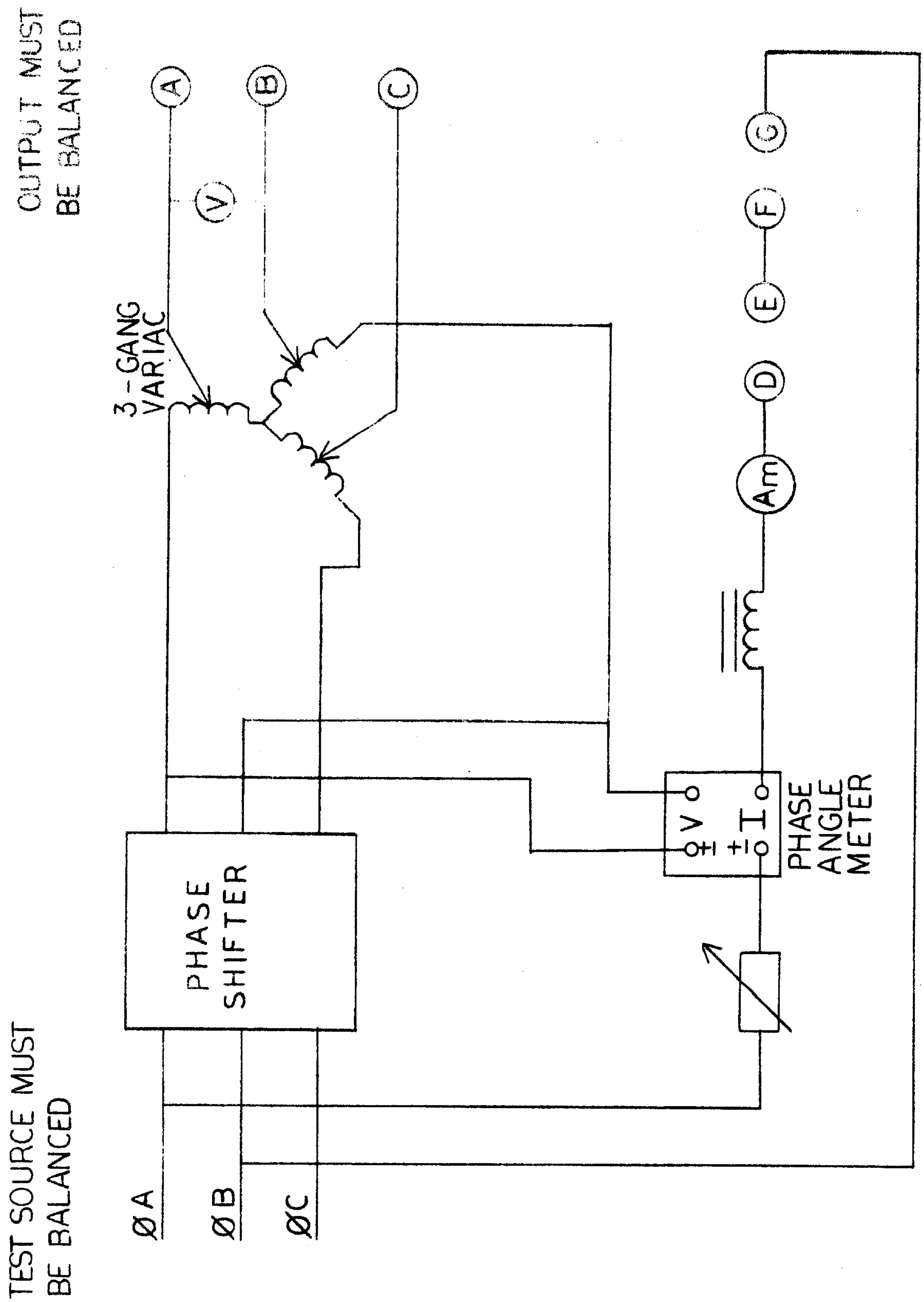
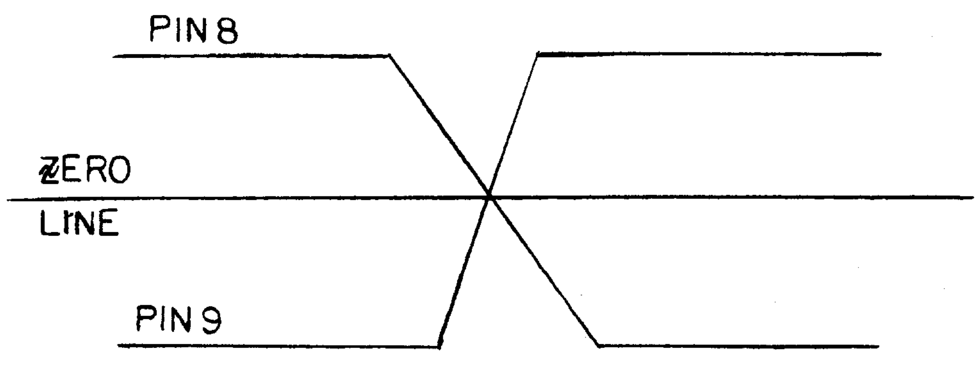
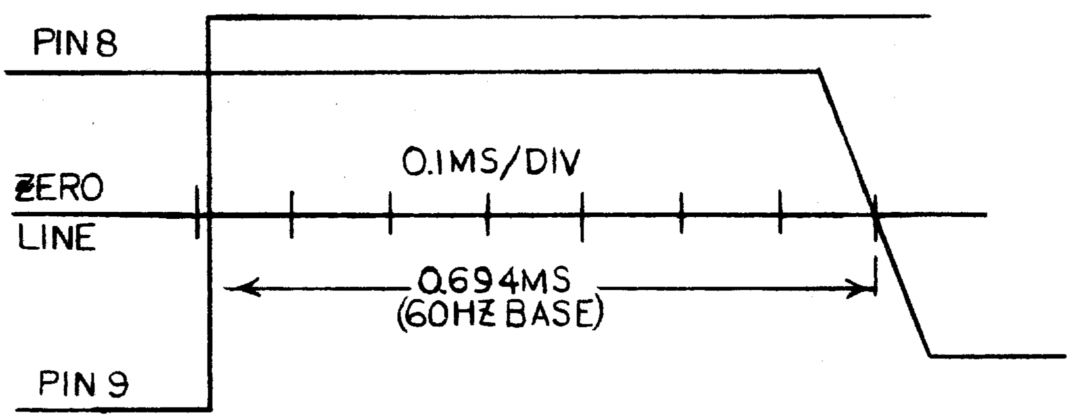


FIG. 7 (0246A6880-1) SLY63A Characteristic Test Circuit



PROPERLY SET 0 DEGREE PHASE SHIFT



PROPERLY SET 15 DEGREE PHASE SHIFT

FIG. 8 (0257A9696-1) Polarizing Circuit Phase Shift Waveforms

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GENERAL ELECTRIC

12/79 10-80

PRINTED IN U.S.A.